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Review

The science of interpersonal touch: An overview

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ABSTRACT

Surprisingly little scientific research has been conducted on the topic of interpersonal touch over the years, despite the importance of touch in our everyday social interactions from birth through to adulthood and old age. In this review, we critically evaluate the results of the research on this topic that have emerged from disciplines, such as cognitive and social psychology, neuroscience, and cultural anthropology. We highlight some of the most important advances to have been made in our understanding of this topic: For example, research has shown that interpersonal tactile stimulation provides an effective means of influencing people's social behaviors (such as modulating their tendency to comply with requests, in affecting people's attitudes toward specific services, in creating bonds between couples or groups, and in strengthening romantic relationships), regardless of whether or not the tactile contact itself can be remembered explicitly. What is more, interpersonal touch can be used to communicate emotion in a manner similar to that demonstrated previously in vision and audition. The recent growth of studies investigating the potential introduction of tactile sensations to long-distance communication technologies (by means of mediated or 'virtual' touch) are also reviewed briefly. Finally, we highlight the synergistic effort that will be needed by researchers in different disciplines if we are to develop a more complete understanding of interpersonal touch in the years to come.

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"We believe that contact comfort has long served the animal kingdom as a motivating agent for affectional responses." (Harlow, 1958, p. 676).

1. Introduction

Touch is the first of our senses to develop, and it provides us with our most fundamental means of contact with the external world (e.g., Barnett, 1972; Gottlieb, 1971). The skin, and the receptors therein, constitute both the oldest and the largest of our sense organs (Field, 2001; Frank, 1957, p. 217; Montagu, 1971). To put this into some kind of perspective, note that the average adult male will have around 18,000 square centimeters of skin, constituting about 16–18% of his body weight (see Montagu,

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1971). The sense of touch provides us with an often-overlooked channel of communication (e.g., Burgoon et al., 1996; Finnegan, 2005; Frank, 1957; Geldard, 1960, 1961; Hertenstein, 2002; McDaniel and Andersen, 1998), and interpersonal touch has been shown to play an important role in governing our emotional well-being (e.g., Field, 2001; Spence, 2002). Whether a strong handshake, an encouraging pat on the back, a sensual caress, a nudge for attention, a tender kiss, or a gentle brush of the shoulder, physical contact can convey a vitality and immediacy at times more powerful than language (Jones and Yarbrough, 1985). Our personal experiences seem to suggest that even the briefest of touches from another person can elicit strong emotional experiences; from the comforting experience of being touched by one's spouse, to the anxiety experienced when we are unexpectedly nudged by a stranger.

We use touch to share our feelings with others, and to enhance the meaning of other forms of verbal and non-verbal communication. For example, our eye contact with other people means very different things depending on whether or not we also touch them at the same time. As Field (2001, p. 57) points out '*Touch is ten times stronger than verbal or emotional contact, and it affects damned near everything we do. No other sense can arouse you like touch...We forget that touch is not only basic to our species, but the key to it.*' In fact, interpersonal touch plays a very important role in our early social interactions and our first lessons in loving often tend to come through the cuddling we receive as infants (e.g., Harlow, 1958). Early tactile sensations can shape our memories and thus drive our future behavior as Sheldon and Arens pointed out as far back in 1932: "*It may need a trained psychologist to discover that the choice of a man's wife was determined by the memory of the soft silkiness of his mother's hair*" (Sheldon and Arens, 1932, p. 100; see also Gallace and Spence, in press, 2008b, for a review of tactile memory). Of course, touch assumes an even stronger role in romantic relationships in adulthood: "*I could die for the touch of a woman like thee*" was how the novelist Lawrence (1928, p. 135) once put it.

On the other hand, a shortage of touch often carries negative connotations, as captured by terms such as 'out of touch with reality' and 'tactless', while a deeply-felt experience is often described as 'touching' (Montagu, 1971, p. 5). As we will see below, interpersonal touch can also provide a powerful means of gaining the compliance of another, or when trying to persuade someone of something (such as in the 'Midas touch' effect; see Crusco and Wetzel, 1984).

The sense of touch provides a very powerful means of eliciting and modulating human emotion. In fact, our skin contains receptors that can elicit emotional (sometimes referred to as affective or hedonic) responses (e.g., Valentini et al., 2007; Weiskrantz and Zhang, 1989), either because there are portions of the skin that are erogenous and deliver positive affect directly, or because there are nerve endings that respond to pain and deliver negative affect (see Auvray et al., in press; Winkelmann, 1959). Recent research has shown that certain parts of the brain, such as the orbitofrontal cortex, respond specifically to 'pleasant touch', such as the feel of velvet on the skin (Francis et al., 1999). However, it is important to note that what we normally think of as the unitary sense of touch (often described as 'haptics')[1] actually consists of a number of different classes of sensory receptors responding to touch, pressure, temperature, pain, joint position, muscle sense, and movement (see Berkley and Hubscher, 1995; Iggo, 1977). There is, however, little agreement as to whether or not these different classes of receptors should be considered as constituting separate sensory modalities or sub-modalities (e.g., Auvray et al., in press; Durie, 2005; Sheldon and Arens, 1932). Although different receptors in the body and skin are sensitive to these various types of 'somatosensory' information, our brains effortlessly bind them all automatically into the unified sense of touch with which most of us are subjectively familiar.

Interpersonal touch provides the most emotional of our tactile experiences. That said, in many situations nowadays, interpersonal touch is actively discouraged, often due to the threat of potential litigation and/or changing public attitudes (e.g., Field, 2001; Ingham, 1989; see also Routasalo and Isola, 1996). Dr Tiffany Field, Director of the Touch Research Institute, in Miami, Florida (who has written more than 100 research articles documenting the beneficial effects of interpersonal touch on health and well-being), has asserted that many people in society today may actually be suffering from a shortage of tactile stimulation, a phenomenon which she evocatively refers to as 'touch hunger'.

Despite its importance for our emotional well-being, the study of the interpersonal and emotional aspects of touch have been somewhat neglected by cognitive scientists over the years[2]. Far more research appears to have been devoted to investigating the more emotional aspects of our other senses, such as vision and audition (and to a lesser extent olfaction and taste), than of our sense of touch (e.g., Ekman, 1993; Ekman et al., 1972; Fecteau et al., 2007; Johnstone et al., 2006; Nass and Brave, 2005; O'Doherty et al., 2001; Veldhuizen et al., 2006).

Studying the cognitive and neural correlates of interpersonal touch together with the more cognitive aspects of tactile perception (see Gallace and Spence, 2008a, in press; Gallace et al., 2007, for recent reviews) seems then to constitute an important issue at present. Indeed, the development and diffusion of internet-based technologies has created the opportunity to easily (and at little, or no, cost to the customer) interact with people who may be many miles away. However, these advances have occurred at the expense of the more physical and, in particular, tactile aspects of interpersonal communication (see also Finnegan, 2005). Researchers in a number of different fields of study are therefore now actively thinking about how to try and bring back touch into internet and virtual reality settings (e.g., see Smith and MacLean, 2007). It is our belief that we may actually be on the verge of a new era of multisensory virtual communications. However, before any real progress can be made in enhancing the realism in the area of virtual or mediated touch, more research will have to be conducted in order to better understand the more cognitive aspects of interpersonal tactile communication. Similarly, those topics, such as the emotional and hedonic aspects of tactile sensations that are closely related with that of interpersonal touch also need to be addressed at the same time (see Fig. 1, for the disciplines relevant to the study of interpersonal touch). This would certainly help to develop a fuller understanding of the science of interpersonal touch in the years to come.

2. The effects of age, gender, and cultural differences on interpersonal touch

Before reviewing the extant literature on the role of tactile stimulation in interpersonal communication, it is worth noting the important role that background and culture can play in modulating

[1] It should be noted that in the cognitive psychology/psychophysics literature, the term 'haptics' has a very specific meaning, restricted to describing those tactile stimuli that impinge on the skin, and which are perceived by means of a person actively palpating an object or surface, such as when actively exploring an object held in the hand. By contrast, the term 'tactile' is used to describe those tactile stimuli that are delivered passively to the skin.

[2] The present review does not deal with the extant research that addressed the effect of massage on people's emotional state and well-being. This topic has been extensively reviewed elsewhere (e.g., see Field, 1998; Field et al., 1996, 2005).

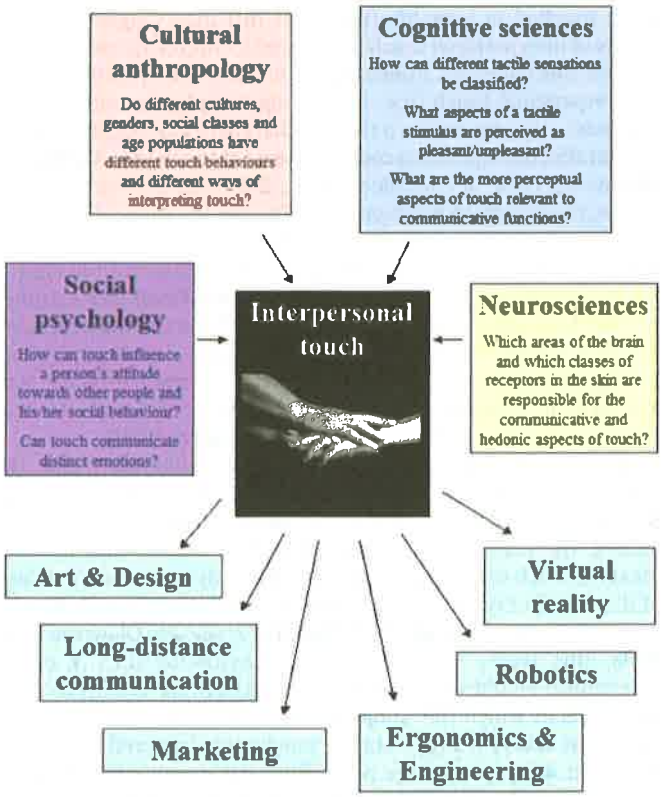
Cultural anthropology
Do different cultures, genders, social classes and age populations have different touch behaviours and different ways of interpreting touch?
Cognitive sciences
How can different tactile sensations be classified?
What aspects of a tactile stimulus are perceived as pleasant/unpleasant?
What are the more perceptual aspects of touch relevant to communicative functions?
Social psychology
How can touch influence a person's attitude towards other people and his/her social behaviour?
Can touch communicate distinct emotions?
Interpersonal touch
Neurosciences
Which areas of the brain and which classes of receptors in the skin are responsible for the communicative and hedonic aspects of touch?
Art & Design
Virtual reality
Long-distance communication
Robotics
Marketing
Ergonomics & Engineering

Fig. 1. Schematic representation of the disciplines relevant to interpersonal touch research (together some of the questions which arise from them) and of the domains that can benefit from the study of this topic.

people's interpretation of, and hence their response to, interpersonal touch (e.g., Jourard, 1966; Maines, 1977; Shuter, 1977). Most people's personal experience provides numerous examples that people belonging to certain cultures touch each other more often than those belonging to other cultures. For example, in Italy, a hug and kiss on each cheek is considered a common and acceptable form of greeting. By contrast, in Japan the proper greeting consists of a respectful bow and the absence of any tactile contact whatsoever (see also Finnegan, 2005; McDaniel and Andersen, 1998). Following on from these everyday observations, the empirical research that has been conducted in this area has confirmed that people from the United Kingdom, certain parts of Northern Europe, and Asia touch each other far less than those in France, Italy, or South America (e.g., Jourard, 1966; see also Henley, 1973).

For example, couples observed in coffee-shops in San Juan, Puerto Rico by Jourard (1966) touched each other an average of 180 times per hour, while those in London cafes averaged 0 touches per hour. The setting in which people interact can, of course, also affect interpersonal touch (e.g., Burgoon et al., 1989). That is, it has been shown that at airport departures and arrivals lounges, approximately 60% of individuals engage in at least some form of interpersonal touch, and quite often in multiple touching between couples (i.e., a comparatively higher rate than that obtained in coffee shops and other public places; see Heslin and Boss, cited in Smith et al., 1980; see also Greenbaum and Rosenfeld, 1980, for a study highlighting the gender differences that exist in the greeting of airline travelers). Similarly, in an observational study of preschool children at play, Williams and Willis (1978) reported higher rates of interpersonal touch when the children were playing outside as compared to when they were playing inside. Field observations have also confirmed that the rate of interpersonal touch following sporting success (in this study, bowlers were observed during league play; Smith et al., 1980) is much higher than that reported in other public settings (and, what is more, was no different for male as compared to female teams).

Belonging to a certain gender and age group can though sometimes have a profound effect on a person's touching behavior. For example, during the preschool years and up to high school, same-gender pairs tend to touch more frequently than cross-gender pairs (see Williams and Willis, 1978; Willis and Hoffman, 1975; Willis et al., 1976). This effect is greater among pairs of females than amongst pairs of males. Interestingly, this relationship appears to change as a function of maturation. Indeed, it has been reported that college students (Willis et al., 1978) and adults in public shopping centers (Daniels, 1978, cited in Smith et al., 1980) have rates of cross-gender touching that exceed those observed in same-gender touching. Furthermore, within cross-gender pairs, males are more likely to initiate the touching of the female than vice versa (e.g., Henley, 1973).

Tactile touching behaviors (i.e., social touch) certainly bare comparison to other forms of social interactions, such as eye contact, that occurs between people. In particular, it has been shown that girls and women are more likely than boys and men to engage in mutual eye contact with another person for longer periods of time, particularly if that person is female (e.g., Argyle and Ingham, 1972; Mulac et al., 1987). That is, females' same-gender eye contact exceeds their cross-gender eye contact (just as has been reported for the case of tactile contact in childhood). Note, however, that research on this topic also suggests the possibility that this pattern of behavior is 'context-specific' and in cross-sex interactions boys and girls may follow a different pattern of mutual gaze than that seen in same-sex interactions (Argyle and Ingham, 1972; Mulac et al., 1987). The similarities and differences between visual and tactile forms of social interactions and the modulating role of context in such aspects of behavior, certainly deserve to be investigated further.

The observations reported in this section clearly suggest that age and gender differences together with cultural factors have to be taken into account when investigating the role of touch as a means of interpersonal communication (see Gumtau, in press, for a discussion of the role of cultural context in tactile communication).

3. Research on the consequences of interpersonal touch

The power of interpersonal touch in different kinds of interpersonal interactions has been shown in many different studies over the last 3 decades or so (see Thayer, 1982, 1986, 1989, for reviews). For example, in one of the classic studies in this area, Fischer et al. (1976) asked male and female clerks to return library cards to some students and while doing so to place their hands directly over the students' palms, making physical contact; other students, by contrast, were not touched. The researchers found that the students' evaluation of the library was more favourable if the library clerk 'accidentally' touched them. Interestingly, this effect occurred despite the fact that none of the students could remember having been touched by the librarian (see also Erceau and Guéguen, 2007, for a similar result showing the people rate salespeople at car showrooms more favourably if they had been touched by them).

It is important to note here that the results of the studies reported thus far in this section were all obtained using post-observation questionnaires in ecologically-valid conditions (as compared to controlled laboratory conditions). As such, it is difficult to determine whether the people who had been interviewed really had been unaware of the touch at the time that it occurred (e.g., when the card was returned by the clerk in

Fisher et al.'s (1976) study) or whether instead they had been aware of the touch at the time that it had occurred but then simply forgot that they had been touched a short time thereafter (see Wolfe, 1999, for a similar distinction between blindness and amnesia for previously-presented visual stimuli).

Subsequent research by Jacob (Hornik, 1991, 1992; Hornik and Ellis, 1988) has shown that interpersonal touch can also be very important in a consumer (i.e., store) setting. In particular, Hornik's research has shown that customers tend to be far more compliant in their behavior (in terms of responding positively to a tasting and purchasing request) in a supermarket when they are touched by an experimenter posing as a store assistant than when no one touches them (Hornik, 1992). Working along similar lines, Kleinke (1977) has also reported that people are significantly more likely to return a dime left in a phone booth if the preceding "telephone caller" touched them than if he/she had not.

Guéguen (2004) reported an experiment in which students were encouraged to demonstrate the solution to a given statistical exercise that had been presented on the blackboard in a classroom setting. A number of the students were briefly touched on their forearm by the teacher during the exercise while the others were not. Next, the teacher asked the students to demonstrate the solution to the exercise on the blackboard. The results demonstrated that touching increased the rate of volunteering by the students (see also Field et al., 1996). Hornik and Ellis (1988) have also shown that individuals who have been touched are more likely to agree to participate in mall interviews.

Elsewhere, Crusco and Wetzel (1984) examined the effects of two types of touch in a restaurant setting. The waitresses in this study were instructed to briefly touch customers either on the hand, on the shoulder, or not to touch them at all as they were returning their change after they had received the bill. Crusco and Wetzel used the size of the tip given by the customer to the waitress as their independent variable. Surprisingly, the researchers found that the tipping rate of both male and female customers was significantly higher in both of the touching conditions than in the baseline no-touch condition (a phenomenon that has been labelled the 'Midas touch' effect; e.g., Crusco and Wetzel, 1984; Erceau and Guéguen, 2007; Stephen and Zweigenhaft, 1986; see also Kaufman and Mahoney, 1999). Meanwhile, other researchers have been able to show that bus drivers are more likely to give a passenger a free ride if they touch him while making the request than if they do not (Guéguen and Fischer-Lokou, 2003). Finally, Joule and Guéguen (2007) have recently demonstrated that people are more likely to give someone a free cigarette if the request comes from a person who touched them at the same time.

At present, it is somewhat unclear why interpersonal touch should have such a powerful effect on people. Rose (1990) has argued that these effects may be due to cognitive interpretational factors. That is, the recipient tends to assume that the 'toucher' is in genuine need and that the toucher likes and trusts him. The perception of either great need or a positive feeling in turn tends to increase compliance rates (see also Patterson et al., 1986). However, although this interpretation might provide an effective means of interpreting the results from those studies in which the 'subject' was aware of the other person's touch, it appears more difficult to extend it to those conditions in which the 'touched' person reported being unaware of the other person's touch (at least if one assumes that interpretational factors act upon a more explicit level of tactile information processing). Investigating the possibility of implicit processing interpersonal tactile sensations represents another important topic awaiting further research.

A somewhat different suggestion has come from Reite (1990) who claimed that the normal association between touch and stress reduction in early childhood may result in a positive response to being touched in later life (note that this may suggest that the effects of interpersonal touch are related to automatic and perhaps implicit mechanisms). Alternatively, however, the positive effects of interpersonal touch (e.g., in eliciting compliance with specific requests) may also relate to the fact that there are receptors in the human skin that appear to code for pleasant touch (e.g., Vallbo and Johansson, 1984; see McGlone et al., 2007, for a recent review). That is, the stored information regarding the situation where touch has been generated can be neurally linked with the pleasant sensations elicited by the touch itself. Reite's interpretation has the advantage of being able to account for the results of those studies in which the participants reported having been unaware of being touched. Indeed, it has been shown that emotional responses can be elicited (likely mediated by subcortical neural pathways; e.g., Morris et al., 1999) without the explicit coding of the stimuli that generated them (e.g., Kunst-Wilson and Zajonc, 1980).

It should be noted here that the interpretation that relates the positive effects of touch on humans to the stimulation of receptors that code for pleasant touch still needs further corroboration. Indeed, the conductive neural fibres (C afferents) that mediate pleasant touch respond particularly vigorously to the slow stroking of the skin, but relatively poorly to rapid deformations of the skin surface (e.g., Bessou et al., 1971; Iggo, 1977; see also Olausson et al., 2008, this issue). Therefore, the activation of such a neural mechanism would seem better able to explain the results of those situations in which the 'subjects' were stroked rather than those situations where a single abrupt touch was delivered. Moreover, one must also consider the possibility that people's beliefs about who is actually touching them (when the eliciting stimulus remains constant) might also play an important role in mediating the effects reviewed in this section.

As far as the link between the neural correlates of tactile sensations and interpersonal social interactions is concerned, it is interesting to highlight the relationship that has been reported recently between touch and certain disorders involving pathologically-abnormal social behaviors, such as autism (e.g., Cascio et al., 2008; McGlone et al., 2007; see also Spitz and Wolf, 1946). Specifically, Zwaigenbaum et al. (2007) have shown that 70% of those individuals affected by autism exhibit some form of sensory-perceptual anomaly. It is also worth mentioning here that infants with autism have often been reported to show an aversion to social touch (see Baranek, 1999). Moreover, it has also been claimed that a pathologically acute tactile sensitivity, or the inability to modulate tactile input, might interfere with social behaviors that involve interpersonal touch (see Grandin, 1992). All of these studies might therefore be taken to strengthen the claim that a change/abnormality in tactile sensitivity has an important impact on a person's social behaviors (see McGlone et al., 2007).

Finally, the effects of tactile contact have also been reported in the context of healthcare-related behaviors, and under conditions where specific physiological variables were measured (Barnett, 1972; Harrison, 1986; see also Routasalo and Isola, 1996, on the debate regarding the 'right to touch and to be touched' in healthcare). For example, it has been reported that the simple act of touching a patient by a nurse on the day before a surgical operation can result in a decrease in the patient's level of stress (both as evaluated objectively by physiological measures such as heart rate and blood pressure and when evaluated subjectively by the patients themselves; see Whitcher and Fisher, 1979). It can even increase the compliance to the preoperative recommendations given to the patient. However, it should be pointed out that in this study, the positive effects of touching were only observed on female patients, whereas the reverse effect was found in male patients. Whitcher and Fisher argued that the differential effect on males and females could have been due to interpretational factors

(that is, they argued that the males may have equated the touch with being treated as an inferior, or dependent, individual, something which they have been socialised to reject), a claim that led Friedman (1980) to subsequently accuse Whitcher and Fisher of being sexist.

Along similar lines, Eaton et al. (1986) have even reported that when the service staff who were caring for elderly people combined their verbal encouragement to eat with tactile contact, they consumed more calories and protein. Perhaps somewhat surprisingly, these positive effects on eating behavior lasted for up to 5 days after the tactile contact! The results of this study would therefore appear to constitute yet another example demonstrating the effectiveness of interpersonal touch on people's compliance (one that in this case also resulted in beneficial physiological changes for the individuals concerned; see also Field, 2001).

In the latter studies (Eaton et al., 1986; Whitcher and Fisher, 1979), it is difficult to separate the influence on people's behavior of tactile stimulation per-se from the interaction between tactile stimulation and any visual and/or auditory components of the interpersonal contact (for example, the tone of voice and/or the facial expression of the nurse). It would therefore be useful in future research to investigate the role of both congruent and incongruent stimulation presented from different sensory modalities in modulating the effect of interpersonal touch. That is, it seems at least possible that social touching might only prove to be effective when combined with (possibly disambiguating) congruent visual and/or auditory information. However, one cannot *a priori* exclude the possibility that tactile information may be capable of overpowering the communicative value of other sources of sensory stimulation, potentially leading to similar effects even when presented within incongruent multisensory settings (see also Finnegan, 2005).

As far as the role of different signals in the effects reported in this section is concerned, it should be noted that most of the studies that have investigated interpersonal touch are not immune from possible important confounds. For example, the variability in the interpersonal distance between various experimental conditions and the fact that the confederate cannot be kept totally blind with respect to the experimental manipulations (and thus he/she might perhaps add further uncontrolled and involuntary social signals to the experimental manipulation) might affect the compliance of participants in many of these experiments (see Lewis et al., 1997, for discussion of this point). As a consequence, the role of touch might have been over- or even under-estimated in previous studies. Certainly, the use of virtual, computer-mediated interactions (resulting in standardized experimental conditions), might offer an important contribution to the reduction of the bias that might have affected previous studies in this field (e.g., Haans et al., 2008a, 2008b).

As we have seen thus far, social touch can have a number of positive effects on people's behavior, but one might question whether this is true in all interpersonal contexts. As any traveler who starts to feel somewhat claustrophobic in an overcrowded train or underground carriage would be able to testify, interpersonal touch certainly does not always carry a positive emotional valence. Unfortunately, only a few studies have thus far been addressed at investigating any negative effects of interpersonal touch (see Major, 1981; Walker, 1971).

A number of researchers have investigated those aspects of tactile behaviour/sensations that are perceived as being 'sexually harassing', and which are therefore described by people as having a negative affective valence (e.g., Gutek et al., 1983; Johnson and Johnson, 1993; Lee and Guerrero, 2001). For example, it has been reported that people consider interpersonal touch to be much more harassing that verbal behavior (Gutek et al., 1983; though see Dougherty et al., 1996). Unsurprisingly, the perception of touch as having a negative valence depends on the specific part of the body that has been touched, and on the specific characteristics of the person (such as his/her gender, age, and relationship with the touched person) who touches it.

For example, Lee and Guerrero (2001) reported that being touched on the face by an hypothetical co-worker was rated by participants as constituting the most inappropriate and harassing behavior (note also that the authors reported that touch on the face was rated as the signal that sends the strongest relational and emotional messages in intimate relationships as well). Touch in the waist region was also considered as being relatively inappropriate and harassing, while tapping on the shoulder was reported to be the least harassing behavior. Results such as these therefore confirm that interpersonal touch may carry both positive and negative affective valence and that the emotional valence that it carries depends on top-down cognitive factors such as gender, context, and cultural factors (see Lee and Guerrero, 2001).

It is of relevance to point out here that Lee and Guerrero's (2001) results were obtained by presenting videotapes showing verbal and tactile interactions between actors and then asking the participants to complete a questionnaire (involving the presentation of Likert-type response scales) regarding the previously-seen interactions. As a consequence, somewhat different, and perhaps even stronger, results might have been expected had the participants in the study been directly touched by another person as compared to the condition in which the participants were only asked to watch a videotape involving strangers touching one another (note though that McCabe et al., 2008, have recently reported that the somatosensory cortex becomes more active when participants observe another person being touched; see also Blakemore et al., 2005; Banissy and Ward, 2007). Moreover, a post-stimulus questionnaire procedure might also enhance the effects of cultural factors (such as the moral judgments of the appropriateness of the interactions) thus making a simple interpretation of Lee and Guerrero's results all the more difficult. Finally, it should be noted that Lee and Guerrero only investigated the effects of being touched on a limited number of body parts, such as the hand, waist, face, and shoulder.

In the future, it would certainly be of interest to investigate both positively and negatively valenced interpersonal (but also mechanical) tactile stimulation presented across more of the body surface using more controlled laboratory conditions (this is of interest because it would hopefully result in the development of a map of our responsiveness to interpersonal touch across the skin surface, i.e., somewhat akin to Weinstein's (1968) maps of the differing sensitivities of the various parts of the bodies of men and women to pressure, temperature, vibration, etc.). The creation of such a map might certainly be useful for the development of devices allowing for long-distance interpersonal interactions to take place (for example, helping to decide where to place the tactile transducers on a virtual reality body suit). Future studies should also help to differentiate the effects that are strictly related to tactile stimulation from those that depend upon any associated change in the interpersonal distance between two individuals. Note that if two people get too close, one of them may perceive a violation of his/her personal space even in the absence of touch (e.g., see Burgoon and Jones, 1976; Dosey and Meisels, 1969; Felipe and Sommer, 1966; Horowitz et al., 1964; Jourard and Friedman, 1970).

Another important aspect of interpersonal tactile communication relates to the question of whether or not touch can provide information regarding the emotional status of another individual. Indeed, previous research has shown this to be true of vision and audition (e.g., Ekman, 1993; Elfenbein and Ambady, 2002; Scherer

et al., 2003). Hertenstein et al. (2006a, 2006b) recently addressed this very topic in a study in which they investigated whether or not people could identify emotions from the experience of being touched by a stranger on their arm (without their necessarily being able to see the interpersonal touch itself). In order to do this, they randomly assigned a group of participants to the role of 'encoder' or 'decoder' of an emotional message. In each trial, the encoder and decoder sat at a table, separated by an opaque curtain that prevented the use of visual cues during the experiment. Twelve emotion words (anger, disgust, fear, happiness, sadness, surprise, sympathy, anger, disgust, fear, happiness, sadness, surprise, sympathy, embarrassment, love, envy, pride, and gratitude) were displayed serially to the encoder. The encoder was then instructed to think about how he or she wanted to communicate each emotion and then to make contact with the decoder's bare arm from the elbow to the end of the hand to signal each emotion, using any form of touch that he or she deemed appropriate. The decoder had to choose among 13 response options which emotion word best described the message communicated by the encoder.

Hertenstein et al.'s (2006a, 2006b) results showed that interpersonal touch could be used to signal at least six different types of emotion, namely: anger, fear, disgust, love, gratitude, and sympathy: The participants in their study were able to decode the emotion in the range from 48% to 83% correct. These values are comparable to the success rates that have been observed in previous studies of the transmission and decoding of facial displays and vocal communication (e.g., Elfenbein and Ambady, 2002). These researchers were also able to identify the specific patterns of interpersonal touch used by their participants in order to communicate the distinct emotions. For example, while a combination of 'hitting', 'squeezing' and 'trembling' (in this order of importance) was used to communicate 'anger', a combination of 'pushing', 'lifting' and 'tapping' was used when 'disgust' had to be communicated. These results then clearly suggest that touch can be successfully used to share emotional aspects of communication between people.

3.1. Touch within a couple

Unsurprisingly, the importance of touch as a means of interpersonal communication has also been documented in romantic relationships (e.g., Gulledge et al., 2003; Hollender, 1970; Montagu, 1979). Note that Montagu (1971) even went so far as to suggest that touch and love are indivisible! Gulledge and his colleagues used a questionnaire methodology in which they asked college students about their preferences and attitudes regarding different types of romantic physical affection (such as backrubs/massages, caressing/stroking, cuddling/holding, holding hands, hugging, kissing on the lips, and kissing on the face) and relationship satisfaction. They reported that tactile physical affection was highly correlated with overall relationship and partner satisfaction. It should also be noted here that gender differences might affect the perception of which sensory modality is actually considered more important for a satisfactory relationship/and in choosing a potential partner (see Herz and Cahill, 1997; see also Nguyen et al., 1975). Clear confirmation of the important role of touch in interactions within the couple also comes from experiments that have used more controlled experimental variables together with questionnaire measures.

The role of tactile affection on physiological variables such as blood pressure and heart rate was investigated by Grewen et al. (2003). These researchers studied the relationship between brief warm (i.e., emotional) social and physical contact among cohabitating couples and blood pressure reactivity to stress in a sample of healthy adults. In their study, the participants were randomly assigned to one of two different experimental groups; the 'warm contact group' underwent a 10-min period of handholding while viewing a romantic video. This was then followed by a 20-s hug with their partner. The no contact group rested quietly for 10 min and 20 s. After this section of the experiment, the participants in both groups had to perform a public speaking task (a stressful event). The results showed that individuals who received pre-stress partner contact demonstrated significantly lower systolic and diastolic blood pressure, and heart rate increases than the no contact group. Given such results, it seems plausible to conclude that affectional physical behavior contributes to lower reactivity to stressful life events. Note, however, that it is also difficult in the case reported by Grewen et al. to completely separate the effect of tactile interaction per-se from that related to the congruency of the tactile sensation with the global context in which it was generated (i.e., the sight of the partner, the videotape, etc.; cf. Moseley et al., 2008).

A recent study by Ditzen et al. (2007) investigated whether specific kinds of physical interaction between a couple can reduce hypothalamic–pituitary–adrenal (HPA) and autonomic responses to psychosocial stress in women. The participants (women who had been married or cohabiting with their male partner for at least 12 months prior the experiment) were randomly assigned to one of three study groups differing in the type of social interaction (lasting 10-min) with their partner that took place prior to stress: No interaction was allowed in one group; In another group, the women received verbal social support; And in a third group, the women received a standardized form of physical contact, consisting of neck and shoulder massage. The participants were then exposed to a standardized psychosocial laboratory stressor (the Trier Social Stress Test). The results showed that those women who received physical partner contact before stress exhibited significantly lower cortisol and heart rate responses to stress (although no significant differences in plasma oxytocin levels were reported) as compared to those women who received social support, or else who received no social interaction whatsoever. Of course, it is also possible in this case that interpersonal tactile contact might have interacted with other congruent aspects (visual, auditory, and even olfactory) of the social interaction with the partner.

A number of studies have investigated the role of touch between partners in mediating the release of oxytocin, a hormone that has been implicated in mammalian bonding behaviors (e.g., Bales and Carter, 2003; Bielsky and Young, 2004; Carter, 1998, 1999; Cho et al., 1999; Insel, 2000; Insel and Hulihan, 1995; Liu et al., 2001; Porges, 1998; Young, 2002). Although the precise mechanisms by which pair bond formation occurs have not, as yet, been specifically delineated, it can be said with some certainty that the release of oxytocin helps couples to form lasting relationship bonds (see Gulledge et al., 2007). Interestingly, the level of oxytocin increases greatly during parturition, perhaps also helping to create an early bond between mothers and their new-born infants (e.g., Kroeger, 1996). Sexual contact tends to induce the largest release of oxytocin (Williams et al., 1992; Winslow et al., 1993; see also Uvanas-Moberg et al., 2005). However, non-sexual physical affection involving tactile stimulation such as backrubbing and hugs has also been shown to induce oxytocin release as well (see Shermer, 2004). Interestingly, women who report having received more hugs from their partners in the past have been shown to have higher levels of oxytocin and significantly lower blood pressure levels than those women who do not have much of a history of being hugged much by their partners (Light et al., 2005).

As far as the role of touch on the more sexual aspects of interpersonal relationships is concerned, the few studies that have

attempted to address this topic scientifically have primarily concentrated on the role of touch in sexual arousal. In particular, convergent evidence now suggests that tactile sensitivity may be associated with sexual arousal and that alterations in tactile sensitivity may impact upon sexual function (see Frohlich and Meston, 2005). For example, Frohlich and Meston reported that the tactile threshold measured at the fingertip was significantly correlated with the presence of female sexual arousal disorder (i.e., the higher the threshold the greater the severity of arousal dysfunction). Moreover, the women's tactile thresholds were linearly related to the severity of arousal dysfunction.

Taken as a whole, the results of the research reviewed in this section would appear to suggest that tactile stimulation plays a very important role in interpersonal communication, sexuality, and in creating bonds between people. This might occur, at least in part, at very low-level stages of information processing in the brain (i.e., mediated by hormone release).

4. The neuroscientific aspects of interpersonal touch

As should have become apparent from the review of the literature thus far, we humans do not treat all of the different kinds of touch that we may experience equally (and as a consequence we respond to and perceive them in a number of different ways). In particular, our brains appear to discriminate between interpersonal touch, intrapersonal touch, and the passive touch of an object or surface on the skin (Bolanowski et al., 1999). What is more, it should also be noted that the majority of studies of interpersonal touch have investigated the consequences of interpersonal touch on non-glabrous (i.e., hairy) skin sites. By contrast, the majority of studies of tactile perception have involved people/participants touching (or being touched by), manipulating, and/or evaluating objects with their hands (i.e., using their glabrous or non-hairy skin). Now while introspection might lead one to assume that all of our skin surface is essentially the same (except for the fact that we are more sensitive on certain skin surfaces than others; e.g. see Weinstein, 1968; Winkelmann, 1959), the latest research has revealed that certain classes of tactile receptors in the skin exist only in the non-glabrous skin but not in the glabrous skin (such as the hands, or the soles of the feet). These observations can be taken to highlight the importance of testing different areas of the body when studying the more hedonic and interpersonal (as compared to perceptual and psychophysical) aspects of tactile information processing (cf. Weinstein, 1968).

Recent cognitive neuroscience research findings have highlighted the fact that the brain differentiates between the more affective aspects of touch and affectively-neutral tactile sensations (e.g., McGlone et al., 2007; Olausson et al., 2008; Rolls et al., 2003; see also Rolls, 2008, this issue). For example, Rolls et al. compared the patterns of brain activation produced by pleasant touch, painful touch (produced by a stylus), and neutral touch (consisting of the contact with the textured end of a wooden dowel), to the left hand using functional magnetic resonance imaging (fMRI). Rolls and his colleagues reported that regions of the orbitofrontal cortex were activated more by pleasant touch and by painful stimulation than by neutral touch, and that different areas of the orbitofrontal cortex were activated by the pleasant and painful touch. The orbitofrontal cortex activation was related to the affective aspects of the touch, in that the somatosensory cortex (S1) was less active following pleasant and painful stimuli than following 'neutral' stimulation.

Researchers studying the neural correlates of the more affective aspects of tactile processing have also suggested that the insular cortex might be an important component of a system responsible for our emotional, hormonal, and affiliative responses to tactile contact between individuals engaged in behaviors such as social grooming and nurturing (e.g., Olausson et al., 2002; Wessberg et al., 2003). It is relevant here to point out that the insular cortex is now thought to contribute to the processing of convergent signals arising from different sensory channels, to produce an emotionally relevant response to a given sensory experience (e.g., see Nagai et al., 2007; see also Craig, 2002; Craig et al., 2000). On the basis of such considerations, one might therefore hypothesize that part of the neural network responsible for the processing of certain emotional aspects of tactile experiences is actually shared with the network responsible for processing information from other sensory modalities.

Unfortunately, however, very little is currently known about the integration of touch and other sensory inputs (e.g., auditory and visual) that may lead to specific and unique patterns of emotions (see Montoya and Sitges, 2006, for the observation of a modulation of somatosensory-evoked potentials when participants were viewing affective pictures; see also Francis et al., 1999, for the neural correlates of the interactions between pleasant touch, olfaction and taste). Moreover, one might also question whether one sensory modality can be more effective in activating emotional neural circuits than the others (and touch, as a function of its relevance for controlling basic body functions and its earlier development, might be the perfect candidate to play a more important role here; cf. Herz and Inzlicht, 2002).

Finally, it is relevant to note in this section that the more emotional aspects of tactile sensations may be also related to the functioning of the neural systems responsible for our memory of tactile sensations (see Gallace and Spence, in press; see also Gallace and Spence, 2008b). Indeed, as far as visual stimuli are concerned, it has been shown that participants have a preference for those stimuli that were already presented in a set, even when they were not able to explicitly recognize them as not being novel (e.g., Harrison, 1977; Kunst-Wilson and Zajonc, 1980; Monahan et al., 2000; Zajonc, 1968). Similarly, we might consider particularly pleasant previously-presented tactile stimuli (such as the strong handshake of a friend of the caress of our partner). Therefore, those areas that are though to process our memories for tactile stimuli, such as the anterior and ventrolateral prefrontal cortex, the posterior parietal cortex, the perhirinal cortex, the insula and the lateral occipital complex (see Gallace and Spence, in press, for a recent review) might well be involved in the more social aspects of touch.

5. The development of touch as a communication system

The role of touch as a means of interpersonal communication seems to have developed in many different animal species. Indeed, touch is an important form of communication for many animals (see Hertenstein, 2002; Hertenstein et al., 2006a, 2006b; Moynihan, 1966; Weber, 2005). For example, mother tigers lick and nuzzle their babies, chimpanzees groom each other, and bear cubs wrestle with each other. In the animal kingdom, touch is used to comfort, to establish dominance, and to establish bonds. Not surprisingly therefore touch seems to be even more important in those species that can be defined as 'social animals'. For example, affiliative bodily contact among dolphins, namely 'flipper-rubbing', has been reported to repair deteriorated relationships or reduce tension within the group following aggressive interactions (see also Tamaki et al., 2006; Terry, 1970).

Similarly, for many primate species living in large groups, interindividual touch has been shown to help the group form bonds and stay peaceful (e.g., Coelho et al., 1983; Lindburg, 1973; Weber, 2005). Primates often groom each other: Female primates often hold and frequently cuddle and comfort their young. What is more,

different forms of touch (on different parts of the body) may be used by these animals to communicate different meanings (e.g., Boccia, 1986). Following on from these observations, it should come as little surprise that touch plays a very important role as a communication modality in humans as well. Indeed, as previously pointed out (in the Introduction), touch is the first sense to develop in the womb and it reaches maturity well before the other senses do (e.g., Atkinson and Braddick, 1982; Bernhardt, 1987; see also Fitzgerald and Gibson, 1984; Miodownik, 2005). It has even been claimed that interpersonal touch can be characterized as one of humankind's earliest form of communication (e.g., De Thomas, 1971; Frank, 1957; Knapp, 1972; McDaniel and Andersen, 1998).

Weiss et al. (2004) tried to determine the relationship between early maternal touch and the neurodevelopmental status of low birth weight (LBW) infants. They recorded mothers' touching behaviour during feeding when the infants were 3 months old and then administered neurodevelopmental tests on the same infants at the age of 1 year. The results indicated that those infants whose mothers used more stimulating touch during care-giving had better visual-motor skills at 1 year of age. In addition, the infants of mothers who touched them frequently had more advanced gross motor development. On the basis of these results, Weiss et al. concluded that stimulating and frequent touch may help to compensate for early neurosensory deficits and promote neurodevelopment for LBW infants (see also Field, 2001; Levine et al., 1967; Rose et al., 1980; Rubin, 1963; Stack, 2001).

Other indirect confirmation of the important role played by interpersonal touch in modulating the wellbeing of newborn babies comes from studies that have investigated analgesic procedures in infants. Specifically, researchers have investigated the role of different forms of stimulation on newborn babies having venepuncture or heel prick (a painful condition; Shann, 2007; see also Fitzgerald and Gibson, 1984). Shaan showed that the distress caused by venepuncture, heel prick, or immunisation can be substantially reduced by use of 0.5 mL/kg 33% sucrose 2 min before the procedure, followed by a cuddle plus either breastfeeding or a pacifier given during the procedure. That is, tactile stimulation (including both suckling and being cuddled), seems to interact with other aspects of the stimulation in reducing babies' painful perception (a phenomenon that has been labelled 'sensory saturation' and which may consist of distracting and comforting babies by massaging them, speaking to them, establishing eye contact, offering a fragrance and placing a 10% glucose solution on the tongue; see Bellieni et al., 2007). More generally, massage has also been reported to have a beneficial effect on a number of different aspects of a baby's well-being (e.g., Dieter et al., 2003; see Underdown et al., 2006, for a review).

These studies appear to demonstrate that interpersonal touch plays a crucial role in the development and well-being of humans; but what about the lack of touch? Can the shortage of those tactile sensations that are generally involved in mother-child interactions (such as the perception of the mothers' body softness or warmth by the baby) have a negative effect on psychological development? This topic was first addressed by the pioneering work of Harry Harlow on baby monkeys (see Harlow, 1958; Harlow and Zimmerman, 1959). In a now-famous series of experiments, Harlow removed baby rhesus monkeys from their mothers, and randomly assigned them to one of two possible surrogate mothers, one made of terrycloth, the other of metal wire. In the first group, the terrycloth mother provided no food, while the wire mother did (by means of an attached baby bottle containing milk). In the second group, the terrycloth mother provided food, while the wire mother did not. Harlow and his colleagues observed that the young monkeys clung to the terrycloth mother no matter whether it provided food or not, and that the young monkeys chose the wire surrogate only when it provided food.

Interestingly, whenever a frightening stimulus was brought into the cage, the monkeys ran to the cloth mother for protection and comfort, no matter which mother provided the food. At a later stage of development, the monkeys that had only had a wire mother were observed to have trouble digesting milk and suffered more frequently from diarrhea (although both groups of monkeys gained weight at the same rate). On the basis of these results, Harlow concluded that not having contact comfort was psychologically stressful to the monkeys. Note, however, that the extension of these conclusions from monkeys to humans by Harlow (together with Harlow's apparent lack of ethical concern for the treatment of his monkeys) has been criticized by a number of researchers in subsequent years (e.g., Cohen, 1996). It therefore seems straightforward to ask what would happen to humans who for whatever reason receive very little tactile contact from their mothers or caregivers.

Several studies have investigated the effect of the deprivation of care at an early age on people's well-being and development. The majority of these studies have investigated the cognitive, social, and neural development of children who had to live for a certain period of their infancy in sub-standard institutions for orphans and who, as a consequence, received minimal parental care. These studies have generally shown that the cognitive and social capabilities of these sensorially- and socially-deprived children are often below the average when compared to children of the same age who had been brought up in normal families or better institutions (see Maclean, 2003, for a review; see also Chugani et al., 2001; Nelson, 2007; for the possible neural correlates of early deprivation in children). In fact, the consequences of this lack of care may still be present years after adoption (e.g., Beckett et al., 2006).

Although common sense might suggest that tactile deprivation plays an important role in this outcome, it is important to note that no definitive conclusions regarding the consequences of the lack of interpersonal touch can be drawn on the basis of these observations. Indeed, basic sensory stimulation in institutionalized children can be lacking across multiple sensory modalities leading to the often reported perceptual and cognitive deficits (e.g., children lack patterned light stimulation because walls and ceilings are painted white, leading to a form of visual deprivation; infants are not held or touched, leading to tactile deprivation, and so on; see Nelson, 2007).

Taken as a whole, the results of the research summarized in this section unequivocally suggest that touch can play a very important role in normal human development. In particular, early tactile experiences (even those taking place in the womb) might strongly contribute to shaping and characterizing the emotional, relational, cognitive, and neural functioning of the adult.

6. Interpersonal touch in the era of virtual communication

As we have already noted in this review, body contact (and gestures) form an important part of the information exchange in our everyday interpersonal experiences. Unfortunately, however, these tactile aspects of communication are completely lacking in long-distance interactions (such as in telephone calls or in internet-based communications). As pointed out by Alapack (2007), nothing, not a fantasy, nor '*a text vanishing at the click of the mouse*', can compensate for the lack of flesh-to-flesh contact in virtual communication and/or relationships (see also Alapack et al., 2005). Although many efforts have been made to ameliorate the visual and auditory aspects of on-line relationships, very little progress has been made toward adding physical contact to internet

and long-distance interactions. That is, current communication devices do not allow people to express their emotions through touch, body language, or gestures (though see the recent success of online virtual words, such as 'Second Life', where gestures and body language have somehow offered a further channel of communication to internet interactions/relationships; see Ward, 2007).

One might, for example, point out that phones, web-cams and other popular communication devices are designed for general consumption and are simply inadequate to support and maintain a certain level of physical intimacy for couples, relatives or friends, who are located elsewhere. Similarly, one major criticism of 'collaborative virtual environments', has been that they lack emotional warmth and nonverbal intimacy (e.g., Mehrabian, 1967; Sproull and Kiesler, 1986). Many researchers have therefore tried to create technological devices to facilitate interpersonal tactile communication. At first, the aim was to assist users with sensory impairments, later to add another layer of information in computer-mediated communication (see Gallace et al., 2007, for a review of the literature on technology-mediated tactile communication), or to simulate physical interaction between a human being and an inanimate object. However, few projects have been explicitly designed to explore virtual interpersonal touch. One of the first attempts in this direction was the Telephonic Arm-Wrestling system developed by White and Back (1986). This system provided a basic mechanism capable of simulating the feeling of arm wresting by connecting two robot arms over a telephone line. The participants who were recruited to test this device reported the impression of wrestling a real human, although delays prevented a fully-immersive wrestle[3].

Further technological developments in the last 10 years allowed for more sophisticated devices to be built. For example, Dobson et al. (2001) created a vibrotactile interpersonal communication device and a newsgroup navigation device ('Vibrobod' and 'What's Shaking') for complementing interpersonal interaction in a digital space. They found that the addition of vibration and temperature in long-distance interpersonal communication successfully facilitated the exchange of emotional and social content. For example, people interpreted a high frequency, intense buzzing vibration as a very active newsgroup. These researchers claimed that touch as a communication medium is well suited to more general concepts like ambience, affect, and urgency, but less so for the transmission of precise, complex information (cf. Gallace et al., 2007). They also concluded that their mappings were so successful that no prior training was needed in order for people to use the system successfully. Moreover, such a device did not seem to require any special skills in order to be used.

Meanwhile, Basdogan et al. (1998) conducted a series of studies in which participants used haptic devices to perform a collaborative task and could feel the digital avatars of one another while performing the task. Basdogan et al.'s results demonstrated that adding virtual interpersonal touch to a visual interaction improved their performance on a spatial task and increased the subjective ratings of "togetherness" (see also Sallnas et al., 2000). Meanwhile, other researchers have tried to provide the users of instant messaging with tactile feedback. For example, Oakley and O'Modhrain (2002) developed the 'Contact IM', a device designed to try and enrich current instant messaging systems by allowing users to send each other haptic instant messages. This interpersonal exchange occurred via the use of force feedback joysticks (see also Rovers and van Essen, 2004, for another example of haptic instant messaging).

By now, many devices have been developed in order to try and maintain physical contact and intimacy for couples in long distance relationships (e.g., Brave and Dahley, 1997; Chang et al., 2002; Gibbs et al., 2006; Gibbs et al., 2005; Motamedi, 2007). For example, the aim of the 'inTouch' device developed by Brave and Dahley was to try and create the illusion that two people, separated by distance, were interacting with a shared physical object. Each user of this system (which consisted of three cylindrical rollers mounted on a base) actually interacted with his/her own object, however, when one of the objects was manipulated (by rotating a roller), both users' objects were affected. More recently, Motamedi presented 'Keep in Touch', a fabric touchscreen interface combining visual and tactile sensations in order to provide a kind of physical intimacy between long-distance couples. In particular, each of the people using this device was presented with a blurred digital projection of his/her partner. Touching their partner's body brought their image into focus thus revealing their features. Unfortunately, a well-controlled experiment designed to determine whether or not such devices do indeed provide an effective means of interpersonal multisensory long distance communication has yet to be conducted.

Another promising device that will probably soon hit the stage of marketing is the Time best invention of 2006 'Hug-Shirt' (http://www.cutecircuit.com/now/projects/wearables/fr-hugs/). This device, which belongs to the category of 'wearable interfaces', according to the producers, allows a person to feel a hug from another user via a mobile network connection. There are a number of sensors embedded in each Hug-Shirt that can detect the strength of the touch, the skin warmth and the heart rate of the sender. The shirt also contains actuators that are apparently capable of recreating the sensation of touch, warmth and emotion for the receiver. This device, that from outside looks exactly like any other t-shirt, has the advantage of being very portable and has excellent connectivity (indeed it uses a Bluetooth communication system linked to a Java enabled mobile phone).

While few of these devices have been tested so far, the results of pilot studies have revealed positive feedback from the potential users. However, other devices are still at a more conceptual level of development. For example, DiSalvo et al. (2003) and Gemperle et al. (2003) envision the 'Hug', a set of devices that can be connected to each other over a mobile phone network. The authors suggest that people might use this system in order to allow asymmetrical bidirectional physical interaction between people. Specifically, a person can stroke or squeeze his or her device, resulting in vibrations and temperature changes in the other person's device. In another 'to-be-developed' project, Mueller et al. (2005) hope to provide the receiver with a sensation that maximally resembles an actual hug by means of an inflatable vest and a koala-bear-like input device.

The studies discussed in this section highlight the growing importance (over the last decade) of trying to create devices which allow long-distance interpersonal tactile communications between people. It seems, at least to us, that in order for these systems to achieve commercial success, further testing will be needed in order to address both the cognitive and affective aspects (and limitations) of human tactile information processing. We also believe that it is only through the interchange between different disciplines (such as anthropology, neurosciences, psychology, social sciences, ergonomics, and engineering) that people will, in the future, be able to communicate by means of tactile, as well as visual and auditory (and perhaps also olfactory) sensations, when they happen to be in different places.

One of the problems with the studies reported in this section is that the majority of the devices that have been developed so far,

[3] It is worth mentioning here that, although time delays in transmitting information increases with the increasing complexity of the information to-be-transmitted, higher computational power and recent advances in long distance communications should soon reduce any lag in tactile distant interactions to levels that are no longer noticeable.

suffer from a lack of robust empirical testing. That is, favoured by the availability of new technologies and higher computational power, new devices are quickly developed and built but tend not to be put under thorough empirical testing. In most of the studies reported in this section, the researchers involved have typically only reported the qualitative judgments of a small sample of participants regarding a particular device (e.g., addressing questions such as if the user can see themselves actively using such a device in a near future, if they think it could provide an useful mean of communication, or sometime just their general impression regarding the device). The critical question to answer here is: do these devices lead to the same (or at least somehow similar) behavioural responses, psychophysiological consequences, and neural activation that could be obtained in real interpersonal tactile interactions? See Haans et al. (2007), for an example of a negative answer to this question, and Haans et al. (2008a, 2008b) for evidence that the 'Midas touch effect' does not appear to occur when people are touched by a haptic device designed to simulate mediated social touch. In fact, it is worth noting here that most of the systems reviewed in this section were designed, perhaps not to replicate or simulate real physical contact, but at least with the effects of touch on our social interactions and physical well-being in mind (see Haans and IJsselsteijn, 2006, for discussion of this point).

Moreover, as we have pointed out elsewhere (see Gallace et al., 2007), we believe that technological advances always need to be related to the advances in our knowledge regarding the functioning of the human cognitive system, and more specifically, regarding the mechanism of tactile and haptic perception (see also Miodownik, 2005). Without a synergy between these different fields of research, we believe that no serious progress toward the goal of adding tactile sensations to long-distance or virtual communication will be possible (as was the case in the 1970's for tactile communication devices; see Gallace et al., 2007, for a review).

7. Conclusions

The results of the research reviewed here show that tactile sensations elicited under ecologically-valid conditions that involve interpersonal interaction can have surprisingly powerful effects on people's behaviors and emotions. Specifically, interpersonal touch appears to be capable of modulating people's compliance with a variety of different requests (e.g., Crusco and Wetzel, 1984; Guéguen and Fischer-Lokou, 2003; Joule and Guéguen, 2007). Interpersonal touch can affect people's attitudes toward particular services (e.g., Erceau and Guéguen, 2007; Fischer et al., 1976), it can facilitate bonding between pairs in a couple or groups in both animals and human (e.g., Boccia, 1986; Coelho et al., 1983; Light et al., 2005), and it plays an even more important role in people's romantic and sexual relationships (e.g., Frohlich and Meston, 2005). Unfortunately, however, the research conducted to date has not, as yet, uncovered the reasons why interpersonal touch has such dramatic effects on people, nor do we know all that much about the cognitive, neural, and physiological mechanisms underlying these behavioral phenomena.

In fact, researchers have only just started to address the neural aspects of interpersonal touch by showing that different patterns of brain activation can differentiate between the more perceptual and the more social aspects of tactile sensation (e.g., McGlone et al., 2007; Rolls et al., 2003; see also Rolls, 2008, this volume). Interestingly, however, the evidence reviewed here highlights the presence of a profound gap between the majority of research that has been conducted under ecologically-valid conditions of stimulus presentation using questionnaire-based procedures and the virtual absence of research that has made use of more controlled laboratory-based conditions of stimulus presentation. Moreover, although a certain amount of research has addressed the physiological and neural aspects of interpersonal touch, the more cognitive aspects of this topic seem to have been nearly completely neglected by researchers. For example, as yet, we still do not know the characteristics of tactile stimulation that are needed in order for it to be perceived by a person as interpersonal (and eventually pleasant/unpleasant) rather than as mechanical (Auvray et al., 2007; see Spence, 2006, on this point). The apparent negligence by the research community with regard to this issue might reflect both the relative of designing experiments where the topic is properly assessed (also because of possible ethic concerns that might constrain experimentation in the field) but also the lack of robust theories to be tested.

Answering these questions will be of vital importance not only from a theoretical point of view, but also from an applied perspective. Indeed, we have seen that technical innovations have allowed us to communicate more interactively and at virtually no cost with people who may be many miles away from ourselves. Unfortunately, however, these new forms of communication have not, as yet, included tactile contact. A few major problems seem to have constrained this choice in the past; One undoubtedly relates to technical limitations. That is, more complex forms of communication require higher bandwidth and computational capacity, which were not available to researchers in this field (see, for example, the lag problem that constrained the use of the arm wresting device developed by White and Back, 1986; see also Marescaux et al., 2001). Now that both bandwidth and computational power would appear to constitute less of a limitation than they were previously, other more theoretical problems are coming to assume a more important role. Specifically, technological innovation seems to require greater theoretical advances in research into the nature of interpersonal touch before it can produce results that are fully effective.

We believe that even the most advanced devices will not be able to deliver something that can approximate to realistic interpersonal touch if we do not know in the first instance what needs to be communicated and how to communicate it. Specifically, what is the role played respectively by caloric, kinaesthetic, proprioceptive, motion, and vibratory cues in informing us that another human being is touching our skin/body? Furthermore, how can tactile sensations be mechanically reproduced if we still lack a proper lexicon of touch (i.e., a classification of tactile sensations; see Spence and Gallace, 2008, for a discussion on this point)? So far, it seems to us that our knowledge concerning tactile perception is still at a relatively early stage of development that does not allow for highly-complex forms of long-distance realistic interpersonal tactile communication to be fully effective (and emotionally fulfilling). Nevertheless, the attempts that have been made so far to add simple forms of tactile interpersonal interactions to long-distance communication seem to offer great promise. We believe that it is only when touch is fully integrated in virtual reality environments and internet technologies that our experience as users of communication-devices will be truly complete and immersive (see Hoffman et al., 1998). Not surprisingly, research in the field of teleoperator systems is now moving faster and faster in order to achieve this important goal (e.g., Lin and Otaduy, 2008; see Gallace et al., 2007, for a review).

Another important aspect that the present review has revealed is the nearly complete lack of research regarding how the tactile aspects of tactile communication interact with visual, auditory and olfactory aspects of our environment. That is, in everyday situations tactile stimulation does not occur in isolation as a form of interpersonal communication (at least for individuals who are

not visually- or auditorily-impaired; see also Finnegan, 2005). Touching your spouse's hand, smiling and saying 'I love you' sounds very different than touching her/his hand and saying 'Dinner is ready!'. But does it also 'feel' different? The rather disappointing answer from the extant tactile research is that we simply do not know! That is, research cannot tell whether, within an interpersonal context, tactile sensations can be modulated by visual and auditory information that is concurrently-presented (though see McCabe et al., 2008, for a recent attempt to address this topic; see also Montoya and Sitges, 2006). Although laboratory-based research on tactile perception clearly suggests that this might be the case (see Rolls, 2008, this volume), these questions should be addressed within the domain of interpersonal touch as well (for example, by evaluating the pleasantness of an interpersonal tactile stimulus, such as a stroke, when presented together with either a happy or angry face/voice). That is, future research will need to investigate whether or not visual information dominates in the domain of interpersonal touch (e.g., Hartcher O'Brien et al., 2008; Spence, 2007) also within an interpersonal context and how we integrate visual, auditory and tactile cues in processing (and making sense of) interpersonal information.

On the basis of the results of the studies that have investigated the more perceptual aspects of multisensory interactions, different combinations of integration strategies can be used by participants as a function of the specific conditions of stimulus presentation (see Ernst and Bülthoff, 2004, for a review). It might also be the case that the degree to which vision or haptics dominates the social aspects of our behavior is related to a principle of 'optimization' that takes into account the variability of the different input signals (e.g., Ernst and Banks, 2002; see also Jansson-Boyd and Marlow, 2007). That is, people might weight the social signals from different sensory modalities as a function of their reliability and then combine them in an optimal fashion (see Argyle and Dean, 1965). Note that, as far as social interactions are concerned, the role of the context and of previous social experiences might provide further variables that need to be added to the model.

In conclusion, this review has highlighted the importance of the more interpersonal aspects of tactile communication for our well-being, as well as how little integration has so far taken place in terms of our knowledge regarding this topic that arises from different domains. We have shown that cultural, perceptual, and neurophysiological factors all need to be considered in order to have a more complete picture of the sense of touch when used within an interpersonal relationship. As a consequence, we believe that further theoretical and applied advances in research on this fascinating topic will be possible only by means of a greater synergy of efforts from different research fields.

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